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13. ABSTRACT (Maximum 200 words) This annual report provides preliminary data on a study examining the influence of a combined resistance and aerobic training program on the manual material handling (MMH) capability and road marching performance of female soldiers. Subjects were 21 female soldiers, 13 of which completed all phases of the investigation. They trained for 14 weeks, performing progressive resistance training 3 days per week, and running and interval training 2 days per week. Compared to values obtained before training, soldiers increased the maximum mass they could lift from floor to knuckle height by 19% (68 to 81 kg, $p < 0.001$) and from floor to chest height by 16% (49 to 57 kg, $p < 0.001$). They improved by 17% their ability to lift 15 kg as many times as possible in 10-min (167 to 195 lifts, $p < 0.001$). They improved by 4% their maximal effort road march time over a 5 km distance, carrying a 23-kg load mass (44.7 to 43.1 min, $p = 0.02$). Data analysis is still ongoing. These preliminary findings indicate that a short term physical fitness program, conducted about 1 hour per day, 5 days per week can substantially improve female soldier's MMH capability and can result in a small improvement in road marching ability.				
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FOREWORD

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INTRODUCTION

Manual material handling (MMH) is the act of lifting, lowering, carrying, holding, pushing and pulling without the aid of mechanical devices (National Institute of Occupational Health and Safety, 1981; Genaidy, Gupta, & Alshedi, 1990b). This type of labor is one of the most stressful for American workers as evidenced by the fact that it accounts for the largest source of compensable work injuries (National Safety Council, 1972; National Institute of Occupational Health and Safety, 1981). In the U.S. Army, military occupational specialties (MOS) with MMH requirements comprise about 63% of all MOS and many of these are heavily populated, accounting for approximately 75% of enlisted spaces. More than 175 MOS require occasional lifting of 45 kg or more and frequent lifting of 23 kg or more (AR 611-201). For example, the mass of a single 155-mm self-propelled howitzer round is 44 kg. Lifting these rounds for loading and firing of the howitzer is performed by one or two soldiers (Knapik, Patton, Ginsberg, Redmond, Rose, Tharion et al., 1987; School, 1984). In a typical field artillery scenario, a soldier may be required to lift and fire 275 rounds per day (U.S. Army Field Artillery School, 1984). Another MOS with heavy MMH requirements is the cargo specialist (MOS 88H). Cargo specialists are required to lift 240 kg in four-soldier teams (prorated at 60 kg per soldier); they frequently lift and carry 64 kg as part of two-soldier teams (prorated at 32 kg per soldier). Many medical personnel (MOS 91C, 91D, 91E, 91F, 91H, 91J, 91L, 91N, 91P) are required to frequently or occasionally lift 82 kg or more (AR611-201).

An increasing number of MOS with heavy lifting requirements have been opened to women since they were integrated into the regular Army in 1978 (Moden, 1989; Myers, Gebhardt, & Crump, 1984). There is an ongoing debate about opening additional MOS (Walker, 1994), many of which will have additional heavy lifting requirements. The proportion of women in the U.S. Army is expanding: in 1983, 9.6% of the U.S. Army was comprised of women (Defense Almanac, 1983); in 1992, it was 11.3% (Defense Almanac, 1992); in 1994, 19% of all new recruits were women (Morganthau, Bogert, Barry, & Vistica, 1994).

Women have substantially less lifting ability than men (Myers et al., 1984; Sharp, Rice, Nindl, & Williamson, 1993; Vogel, 1985), presumably due to women's lower muscle strength. Women have about 55% the strength of men in the upper body (arms and chest) and 72% the strength of men in the lower body (legs). Overall, the strength of women is about 63% that of men (Knapik, Wright, Kowal, & Vogel, 1980; Laubach, 1976). Much of this strength difference may be accounted for by the lower muscle mass of women (Baumgartner, Rhyne, Troup, Wayne, & Garry, 1992; DeKoning, Binkhorst, Kauer, & Thijssen, 1986; Knapik, et al.,

1980; Wilmore, 1974), since the major determinate of strength appears to be the cross-sectional area of muscle tissue (Maughan, 1984). Systematic resistance training has been shown to increase the strength and muscle mass of both men and women (Cureton, Collins, Hill, & Mcelhannon, 1988; O'Shea & Wegner, 1981; Wilmore, 1974; Wilmore, Parr, Girandola, Ward, Vodak, Barstow et al., 1978) and may be a method for increasing women's capability in MMH tasks.

Using resistance training to improve MMH capability is a relatively new concept (Asfour, Ayoub, & Mital, 1984). Traditional ergonomic approaches to reducing worker job stress during MMH has largely focused on redesigning the working environment through changes in equipment or task requirements (Kantowitz & Sorkin, 1983). However, cost considerations and interference with existing work processes often limit the usefulness of these techniques. For example, it is difficult to modify the shape or mass of a howitzer shell because these factors are dictated by the ballistic and aerodynamic nature of the round and the charge necessary for the explosive effect.

The major purpose of this investigation was to examine the influence of a traditional physical fitness program on improving the MMH capability of women. The program emphasized muscular strength and endurance exercises since this is the type of fitness training most likely to improve MMH capability (Asfour, et al., 1984; Sharp, Harman, Boutilier, Bovee, & Kraemer, 1993). However, the program also included aerobic training since this component of physical fitness is necessary to enhance many of the other tasks that soldiers must perform (FM 21-20).

BACKGROUND

This section presents a definition of physical fitness. It provides a literature review of female adaptations to resistance training and improvement of MMH through resistance training.

Physical Fitness

Physical fitness can be defined as a set of attributes (or components) that enhance an individual's ability to perform occupational and leisure-time activity without undue fatigue (Caspersen, Powell, & Christenson, 1985; Pate, 1983). The components of physical fitness include cardiorespiratory endurance (aerobic capacity), muscular strength and muscular endurance. Cardiorespiratory endurance is the ability of the circulatory and respiratory systems to supply fuel to sustain long term physical activity (e.g., road marching, long distance running, bicycling). Muscle strength is the ability of a muscle group to exert a maximal force (e.g., lifting as much weight as possible). Muscular endurance is the ability of a muscle group

to perform short term, high intensity physical activity (e.g., repetitively lift 44 kg artillery shells as fast as possible) (Caspersen, et al., 1985).

Development of Muscular Strength and Muscular Endurance

Progressive resistance exercise is the most commonly employed technique for improving muscular strength and muscular endurance. The concept of progressive resistance was developed by CPT Thomas Delorme during his work on rehabilitating soldiers following WWII (Delorme, 1945; Delorme, 1948). He noted a difference between low resistance, high repetition exercise which developed endurance, and high resistance, low repetition exercise which developed strength. He formed the concept of the one-repetition maximum (1RM) and ten-repetition maximum (10RM) which are the maximal amounts of weight that can be lifted by a particular muscle group one time or ten times, respectively. Delorme prescribed that individuals should train with the 10RM, performing three sets on each muscle group (Delorme, 1948). He wrote that the mass lifted should be gradually and systematically increased (hence, the term "progressive").

Fifty years of subsequent research has verified and expanded many of these ideas. There appears to be a continuum of "repetitions maximums" (RM) which have different effects on muscular strength versus muscular endurance (Anderson & Kearney, 1982). Maximal strength appears to be most effectively developed with multiple sets of a 3 to 6RM (Atha, 1981; Fleck & Kraemer, 1988); muscular endurance is best developed with multiple sets at higher repetitions (i.e., 15 to 20 repetitions) (Fleck & Kraemer, 1988).

Female Adaptations to Progressive Resistance Training

Table 1 shows studies that have examined changes in women's strength in response to progressive resistance programs. Each investigation uses a different training program, possibly accounting for the wide variations in results. Two studies (Capen, Bright, & Line, 1961; Oyster, 1979) did not specify their training programs and used testing devices that differed from devices used for training (i.e. dynamometry (Capen et al., 1961)) or cable tensiometry (Oyster, 1979). Only two studies lasted 12 weeks (Butts & Price, 1994; Gettman, Ward, & Hagan, 1982); most were 10 weeks or less. The one long term study (24 weeks, Brown & Wilmore, 1974) used nationally ranked track and field athletes, only one of whom had previous, consistent experience with resistance training. These athletes are probably not representative of the general population in terms of strength gains but showed impressive improvements over the training period.

Strength training studies that have examined both men and women under the same training regimens (Cureton et al., 1988; Gettman et al., 1982; Hunter, 1985; Wilmore, 1974; Wilmore, et al., 1978) show that women generally make greater relative gains in strength than their male counterparts. However, the men's absolute strength always exceeds that of women, and after training, the average women does not achieve the absolute strength of the average untrained man.

Table 2 shows studies that have examined women's body composition changes in response to resistance training. For programs as long as 12 weeks, increases as great as 2.3 kg of whole body fat free mass and decreases of 1.9 kg of body fat were seen. The study of longer length that used the elite track and field athletes (Brown & Wilmore, 1974) showed changes that were similar to the short term studies. Studies making direct comparisons between men and women show similar absolute changes (Gettman et al., 1982; Hunter, 1985; Wilmore, 1974).

Table 3 shows changes in body girths in response to resistance training programs. In general, the magnitude of the changes is very small. This could be attributed to the nature of the training programs that emphasized the development of muscular strength and endurance rather than muscle hypertrophy directly. Higher training volumes (more sets and repetitions) appear to be necessary if the goal of training is hypertrophy (Stone, O'Bryant, Garhammer, McMillian, & Rozenek, 1982). Girth changes are similar in men and women in the two studies that made direct comparisons (Hunter, 1985; Wilmore, 1974). One study used computed axial tomography (CAT) scans to directly examine muscle hypertrophy in men and women (Cureton et al., 1988). Changes in upper arm muscle cross-sectional area were examined before and after 9 weeks of arm curl and triceps extension training. Relative increases in arm muscle cross-sectional area were 16% for men and 32% for women. Absolute changes in area were not significantly different between genders.

Progressive Resistance Training and MMH Tasks

The use of progressive resistance principles to improve MMH tasks is relatively recent. In the earliest study (Asfour, et al., 1984), 10 male college students trained for a total of 30 sessions (5 days a week for 6 weeks). For strength training they performed three sets of a 6RM, lifting a box to three different heights (nine sets total). For muscular endurance training they performed 10 minutes of continuous lifting involving light loads and high lifting frequencies (6 to 9 lifts a min). For cardiovascular endurance training they performed cycle ergometer exercise, 30 minutes each session. At the end of the program, improvements in mass lifted ranged from 41 to 99% and estimated cycling VO_2max (from heart rate) improved 23%.

Another early study (Sharp & Legg, 1988) used a unique psychophysical approach. Eight male soldiers selected the maximal mass they thought they could lift to a distance of 132 cm for 1 hour at a rate of 6 lifts a min. Subjects were trained with the self-selected loads during 20 sessions (5 days a week for 4 weeks), lifting in two 15-minute periods each session. At the end of training, the self-selected box mass had increased 26%, 1RM box lift increased 7%, and VO_{2max} (measured in repetitive lifting) increased 6%.

Several studies have been performed by Genaidy and coworkers (Genaidy, Davis, Delgado, Garcia, & Al-Herzalla, 1994; Genaidy, 1991; Genaidy, Bafna, Sarmidy, & Sana, 1990a; Genaidy, et al., 1990b; Genaidy, Mital, & Bafna, 1989; Guo, Genaidy, Warm, Karwowski, & Hidalgo, 1992). All these investigations used tasks involving lifting, carrying, pushing and pulling. Subjects trained for periods of 2.5 to 6 weeks (8 to 24 sessions) on the same task for which they were tested. In general, training resulted in a) progressive improvements in endurance time (time to volitional exhaustion) ranging from 46% to 1350%, b) increases in the isometric strength of the shoulders, arms, legs, and back, c) little or no change in the rating of perceived exertion and d) a decrease in activity heart rate, suggesting an improvement in cardiovascular endurance.

Critique of Progressive Resistance, MMH Studies

All MMH studies cited in the previous section used male subjects with the exception of one (Genaidy, et al., 1994) which used both males and females but did not separate them in the data analysis. All studies used the same task for training and testing. It is probable that the improvements seen were attributable not only to improved strength and endurance but also to improved psychomotor learning. In fact several studies (Genaidy, 1991; Genaidy et al., 1990a; Genaidy et al., 1989) noted that at least some of the gains in endurance and maximal lifting capacity were attributable to improved MMH "technique". Thus, the proportion of the improvement due to physical conditioning alone cannot be culled out from these investigations. This is an important practical question because physical training in the military is assumed to improve a soldier's ability to perform physical tasks (as well as the soldier's health). If physical capability is not improved, some of the time devoted to physical training might be better spent on specific skill-centered occupational training.

The MMH investigations cited above were conducted for no longer than 6 weeks, and most for 4 weeks or less. It has been demonstrated that neural adaptations account for the majority of strength gains in the first few weeks of resistance training, with hypertrophy becoming a more dominant factor later in

training (Moritani & deVries, 1979). Early neural adaptations include fuller activation of prime movers, reduced co-contraction of antagonistic muscles, improved coordination of muscle involved in the intended movement and a removal of inhibitory influences (Moritani & deVries, 1980; Sales, 1988). Muscle hypertrophy is an important factor in strength gains because absolute muscle strength and endurance are proportional to the cross-sectional area of muscle tissue (Maughan, 1984; Tuttle, Janney, & Salzano, 1955). While neural adaptations may be important, the hypertrophy that results from resistance training might be expected to be the major mechanism through which physical capacity for MMH is improved.

Two studies (Murphy & Nemmers, 1978; Sharp et al., 1993) attempted to determine the effects of physical training alone on MMH capability. Murphy and Nemmers (Murphy & Nemmers, 1978) trained 13 women using both resistance training and running with the goal of improving their ability to load and fire howitzers. The women performed 3 sets of 5 reps or 5 sets of 15 reps on 8 traditional resistance training exercises over an unspecified time. Subjects increased their running distance from 0.5 to 2.5 miles over the training period. At the end of the training period, strength was increased 20% to 38%, depending on the muscle group. Also at the end of training the authors state that the women could meet prescribed rates of fire on 155 mm and 105 mm howitzers. However, no howitzer firing data are presented. There is no evidence of a howitzer fire pretest so it is not known if the women could have met the firing rates before the training program.

Sharp et al. (Sharp et al., 1993) trained 18 men for 36 sessions (3 days per week, 12 weeks), using 3 to 5 sets of 10 traditional weight training exercises. MMH tasks consisted of 1) a 10-minute maximal speed lifting of a 41-kg box from floor to chest level and 2) a 1RM for the same distance. After the training program, there was a 17% improvement in the 10-minute task (79 to 92 lifts per 10 minutes) and a 23% improvement in the 1RM task (73 to 89 kg). This study shows that a well-designed resistance training program fashioned to improve the muscle strength and endurance of men can augment the performance of men on MMH tasks.

Physical Training and Road March Performance

Road marching is another task requiring the carrying of loads, not necessarily in the hands, but generally on other parts of the body. It is a frequently performed military exercise and one might well question whether fitness training can improve this aspect of soldier performance. Two studies (Knapik, Bahrke, Staab, Reynolds, Vogel, & O'Connor, 1990; Kraemer, Vogel, Patton, Dziados, & Reynolds, 1987) have examined this question. One

investigation (Knapik et al., 1990) involved 102 male soldiers who were placed into one of four groups performing none, one, two or four road marches per month. All groups completed 1 hour of daily physical training which included both resistance training (2 days a week) and cardiorespiratory training (3 days a week). Before and after the training, the soldiers were asked to complete a 20-km road march as fast as possible while carrying a 45 kg load mass. At the end of the training program, the groups performing road marching two or four times per month were significantly faster than the groups performing no marching or only marching once a month. There were no differences between the two and four march per month groups.

This study suffers from problems similar to those cited previously: there is no way to separate improvements due to psychomotor learning from those attributed to improved physical capability. However, a study by Kraemer et al. (1987) sheds light on this problem. Kraemer et al. trained 35 male soldiers for 12 weeks during one of four programs. Program 1 involved upper and lower body resistance training with running. Program 2 involved upper body resistance training only with running. Program 3 involved both upper and lower body resistance training but no running. Program 4 involved running but no resistance training. All programs were conducted 4 days per week; in Programs 1 and 2, there were 4 days of resistance training and 4 days of running. Before and after the programs, soldiers were asked to complete as rapidly as possible a 3.2-km distance while carrying a total load of 45 kg. At the end of training, subjects in Programs 1 and 2 significantly improved their road march completion time (15% and 11%, respectively) while subjects in Programs 3 and 4 (resistance training alone or running alone) did not. This study indicated that resistance training must be combined with cardiorespiratory training to improve road march capability.

OBJECTIVES

It is known from studies cited previously that women can increase their muscular strength as a result of progressive resistance training. However, it is not known if these strength improvements will translate to significant improvements in MMH capability or road marching performance as has been found with men. Therefore, the major objectives of this investigation were to examine the influence of a fitness program on women's MMH capability and road march performance. The fitness program emphasized resistance training but also included cardiorespiratory endurance training. Secondary objectives were to describe changes in body composition, body circumferences, cardiorespiratory endurance, and muscle strength in response to the fitness program.

BODY

METHODS

Subjects

Subjects were 21 female soldiers who volunteered for this investigation after a full briefing about the purposes and risks of the study. They gave their informed voluntary consent to participate and signed a Volunteer Agreement Affidavit in accordance with Army Regulation 70-25. All subjects were healthy as determined by a medical records review. The military occupational speciality (MOS) distribution was 8 military police, 4 personnel specialists, 3 administrative personnel, 2 food service personnel, 1 supply specialist, 1 medical personnel, 1 wheel vehicle mechanic, 1 legal specialist. Subjects had a mean (\pm SD) time in service of 7.1 ± 5.8 years.

Only 13 subjects completed all phases of the study. Five subjects voluntarily left the study during training and three were removed on the advice of medical personnel. The MOS distribution of the 13 soldiers finishing the study was 4 military police, 1 personnel specialist, 3 administrative personnel, 2 food service, 1 supply specialist, 1 wheel vehicle mechanic, 1 medical personnel. Average time in service for these 13 soldiers was 7.8 ± 6.0 years. Unless otherwise noted, analysis of the data is based on the 13 subjects completing the study.

Study Design

The study involved a pretest-posttest design with 14 weeks of training interpolated between the two tests. The pretest and posttest were essentially identical as described below. Additional measures of strength and nutritional intake were obtained during the physical training period.

Pretraining and Posttraining Measures

Anthropometry and Body Composition

Subjects' total body mass was obtained from a digital scale (Seca®) and their stature from an anthropometer (GPM®). The subjects' age was determined from date of birth. Circumference measures were obtained from the upper arm, shoulders, chest, abdomen, thighs and calf (Clauser, Tebbetts, Bradtmiller, McConville, & Gordon, 1988; Lohman, Roche, & Martorell, 1988) using a fiberglass tape (Gulick®).

Body density was measured by the underwater weighing technique (Fitzgerald, Vogel, Milette, & Foster, 1988) with correction for residual lung volume (Wilmore, Vodak, Parr, Girandola, & Billing, 1980). Residual lung volume was determined

by nitrogen dilution using a Gould® Model 2180 spirometer. Total body fat mass was calculated from body density using the Siri equation (Siri, 1961). Fat-free mass was obtained by subtracting body fat mass from total body mass.

MMH Tasks

Subjects performed three MMH tasks all of which involved lifting a 23 X 30 X 51 cm (9 X 12 X 20 inch) box from the floor. A straight-back, bent knee lifting technique was encouraged but not required.

The first MMH task involved lifting the box from the floor to an upright body position (knuckle height) with as much weight as possible (floor-to-knuckle lift). The second task involved lifting the box from the floor to the chest height with as much weight as possible (floor-to-chest lift). These lifts are representative of typical military MMH tasks such as lifting tools, sandbags, projectiles or boxes of ammunition to various heights (Myers, et al., 1984). For both of these lifts, a 1RM procedure was used (Fleck & Kraemer, 1987). Subjects began lifting a light mass and the mass was increased in a systematic manner (2 to 10 kg) until a mass was found that the subject could not lift. The last weight successfully lifted was recorded as the 1RM.

The third MMH task required subjects to lift a 15-kg box as many times as possible in 10 minutes. The distance lifted was from the floor to chest height. The box was lowered by two spotters on either side of the box. At the end of 5 minutes, subjects were allowed a 1-minute rest. During this rest, subjects were asked for a rating of perceived exertion (RPE, (Borg, 1970) for the upper body, lower body and overall. To obtain the RPE, subjects viewed a 15-point scale containing numbers ranging from 6 to 20. Every other number was associated with a verbal anchor ranging from "7 very very light" to "19 very very heavy". Subjects provided a single numeric rating to describe their exertion. At the end of 10 minutes of lifting, subjects were asked for a second RPE.

A previous study (Sharp et al., 1993) indicated that three trials were necessary to assure stable baseline performance of MMH tasks. Thus, three trials were used to determine reliability and establish a criterion score (Kroll, 1967; Safrit, 1976) in the pretraining phase. In the posttraining phase, only two trials were conducted since data analysis from our study indicated no differences among the two posttraining trials. Each trial was separated by 5 to 7 days.

Road March Task

For the road march task, subjects completed a 5-km distance as fast as possible while carrying a load mass of 23 kg. The load mass included 1) uniform and boots, estimated at 4 kg, and 2) an all-purpose, lightweight, individual carrying equipment (ALICE) pack, symmetrically loaded with a total mass of 19 kg. The march course was entirely on paved roads with very little grade.

One practice march was conducted so that subjects could become acquainted with the course and equipment. For this march, subjects walked at their own pace and no time was recorded.

Two days after the practice march, subjects completed a maximal effort criterion march with time recorded at 1-km intervals. Two to five days after this, a second criterion march was conducted.

Two criterion pretraining marches were conducted because previous research (Kraemer, et al., 1987) indicated that this was sufficient to assure stable baseline performance. Only one march was conducted in the posttraining phase since data analysis from our study indicated no differences among the two criterion pretraining trials, in consonance with the previous investigation (Kraemer et al., 1987).

Army Physical Fitness Test (APFT)

The APFT involved sit-ups, push-ups, and a 3.2-km run using the procedures described in Army Field Manual 21-20 (Physical Fitness Training). Subjects were asked to perform as many sit-ups as possible in 2 minutes and as many push-ups as possible in 2 minutes. Subjects were also asked to complete the 3.2-km run as fast as possible. Total points were calculated from the age and gender related standards in Army Field Manual 21-20.

Previous Physical Training

To assist in determining starting levels of training, soldiers were asked a series of five questions about their previous physical training: 1) "How many times have you run in the last two months?" 2) "On average, how many miles did you run each time you ran in the last 2 months?" 3) "On average, how many minutes did you run each time you ran in the last 2 months?" 4) "How many times did you perform weight training in the last two months?" 5) "On average, how many minutes did you spend in weight training in the last two months?"

Resistance and Endurance Training

The training program was 14 weeks long. The first 2 weeks (seven sessions) were reserved primarily for familiarization and instruction. Subjects were instructed on procedures, safety, proper resistance training techniques, weight room etiquette, exercise progression, clothing for various environmental conditions, running shoe selection and how to monitor exercise heart rate. Subjects performed both resistance training exercises and running but the emphasis was on form and technique rather than training volume. All instruction was performed by an individual certified by the American College of Sports Medicine as Health and Fitness Instructor and by the National Strength and Conditioning Association as Strength and Conditioning Specialist.

During the last 12 weeks of training, resistance exercises were performed 3 days per week on Monday, Wednesday, and Friday while cardiorespiratory training was performed 2 days per week on Tuesday and Thursday. Subjects kept a log of their training from which exercise adherence was calculated.

Resistance Training

Resistance training consisted of nine exercises using exclusively free weights. The exercises were the power clean, deadlift, squat, bench press, upright row, triceps extension, arm curl, lateral raises, front raises. Subjects were instructed to complete the larger muscle group exercises first and alternate arms and legs as much as possible. In the third, fourth and fifth week of training (of the 14-week program), subject performed one, two and three sets, respectively, of ten repetitions on each exercise. A mass was selected that would allow the subject to just complete the ten repetitions. From the fifth to fourteenth week, subjects were encouraged to perform the maximum number of repetitions possible on the last set (up to 13); if 13 repetitions could be completed, the mass was increased by 5% to 10%. At least one instructor (usually two) was present in the weight room at all times to actively monitor and motivate subjects and reinforce correct lifting techniques.

To specifically improve performance of the APFT, soldiers performed push-ups on Tuesdays and Thursdays and sit-ups on Mondays, Wednesdays and Fridays. For the first 7 weeks, subjects performed 75% of the repetitions they had performed on their pretraining APFT. They performed 1, 2, and 3 sets on weeks 2, 3, and 4, respectively, then 3 sets through week 7. Three sets were maintained and repetitions were increased to 80% of the pretraining APFT values on weeks 8 through 11. Three sets were maintained, and repetitions were increased to 90% of the pretraining APFT values on weeks 12 through 14.

Strength Evaluation

In order to evaluate changes in strength, subjects performed a 1RM on six exercises during weeks 3, 7, and 14. The exercises were the squat, deadlift, bench press, upright row, arm curls and triceps extension. Subjects began lifting a light mass and the mass was increased progressively and systematically until a load was found that the subjects could not lift. The last mass successfully lifted was recorded as the 1RM (Fleck & Kraemer, 1987).

Cardiorespiratory Endurance Training

Subjects were placed into one of three cardiorespiratory fitness groups based on their pretraining 2-mile run time and recent running history. Individuals ran together in these groups for the first 4 weeks. Initial mileage was set at 1.5 miles and increased during a 4-week period until all groups were running 3 miles. During this time, one instructor ran with each group. At the end of the 4-week period, subjects were allowed to run individually, all on the same course with at least one instructor (usually two) on the course at all times. Subjects were encouraged to decrease their time over the 3 mile distance in subsequent weeks.

At week 6 (of the 14-week program), interval training was introduced and performed once a week thereafter. On interval days, subjects ran 2 miles then performed four, 402-meter (440 yards) repeats on a standard asphalt track. Initial running times were 15% faster than subjects' average 1/4 mile on the pretraining APFT two-mile run. The work:rest ratio was initially 1:1.5 and was reduced to 1:1 as training progressed (Fox & Mathews, 1974). Since subjects began the interval as a group, the rest interval in practice was about 3 minutes at the start of interval training and gradually reduced to less than 2 minutes as training progressed.

Nutritional Intake

Subjects completed 3-day dietary histories during weeks 2, 6, and 13. Subjects were asked to fill out a form that asked them food name, amount eaten, brand name or restaurant, and how each food was prepared. Sections for breakfast, lunch, dinner and snacks were included. They were told to complete the histories for a Sunday, Monday and Tuesday period. Dietary histories were analyzed using the DINE Healthy® computerized nutritional system.

Injuries

An injury was defined as any musculoskeletal problem that caused the subject pain or concern and that persisted for several training sessions. All injuries occurring during the study were referred to physicians or the physical therapist. The complaint was diagnosed by the medical personnel. Independent records were kept by both the trainer and medical personnel regarding the subject's condition and progress.

RESULTS

As of 1AUG95 we have completed the physical training program as well as pretesting and posttesting. Data analysis is progressing. For the purposes of this report, we have completed preliminary analysis of the manual material handling tasks and road march performance. These results are presented below.

MMH Capability

Table 4 shows the three trials obtained on the three MMH tasks in the pretraining phase. There were significant differences among the trials for all three tests. The Tukey test revealed that in all cases, Trial 1 differed significantly from Trials 2 and 3 but there were no significant differences ($p < 0.05$) between Trials 2 and 3. Thus, trials 2 and 3 were averaged and treated as the pretraining score (Kroll, 1967). Intraclass correlation coefficients for Trials 2 and 3 were 0.93, 0.99 and 0.97 for the floor-to-knuckle, floor-to-chest and 10-minute repetitive lift, respectively.

Table 5 shows the two trials taken on the three MMH tasks during the posttraining phase. There were no significant differences ($p < 0.05$) between posttraining Trials 1 and 2 on any of the tasks. Thus, the Trials 1 and 2 were averaged and treated as the posttraining score.

Table 6 shows the changes in performance of the three MMH tasks from the pretraining to the posttraining. Subjects improved their performance by 19%, 16%, and 17% on the floor-to-knuckle, floor-to-chest, and repetitive lifts, respectively.

The average \pm SD distances for the floor-to-knuckle and floor-to-chest lifts were 70.0 ± 4.2 cm and 119.6 ± 7.0 cm, respectively.

Road March Performance

For road march criterion Trials 1 and 2, average \pm SD 5-km march times were 44.9 ± 3.3 and 44.4 ± 2.6 , respectively. There was no significant difference between these 2 times ($t(12) = 0.96$,

$p=0.36$). Thus, trials 1 and 2 were averaged and treated as the pretraining score. The intraclass correlation coefficient for the two trials was 0.89.

Table 7 shows the pretraining and posttraining road march times at each kilometer of the march. Subjects completed the march significantly faster in the posttraining phase ($t(12)=2.60$, $p=0.02$).

DISCUSSION

The major preliminary finding of this investigation was that traditional physical fitness training was effective in improving the manual material handling capability and road marching performance of U.S. Army women. These improvements occurred with a training duration of about 1 hour per day, and training frequency of 5 days a week, in consonance with the maximum amount of time normally allotted to this activity in the U.S. Army (Army Regulation 350-41). The program progressively increased training volume in a systematic manner during the training period.

MMH Performance

Our study employed a fitness program that did not involve any training with the actual manual material handling task. The only times that subjects experienced the MMH tasks was in the pretraining and posttraining phases. A number of studies (Asfour et al., 1984; Asfour, Koshy, & Genaidy, 1991; Genaidy, et al., 1994; Genaidy, 1991; Genaidy et al., 1990a; Genaidy et al., 1990b; Genaidy et al., 1989; Guo, et al., 1992; Sharp & Legg, 1988) have trained subjects on the same task used for testing. These investigations do not allow separation of the influence of physical training from the influence of psychomotor learning.

The influence of psychomotor learning (e.g., improved lifting technique) appears to be large, relative to the effects of physical training alone. Physical training accounted for performance improvements of 16% to 19% for the women in this study and 19 to 23% for men in a similar traditional physical training study (Sharp, et al., 1993). This contrasts with relative improvements of 46% to 1350% reported for endurance times in studies using the same task for training and testing (Asfour et al., 1984; Asfour et al., 1991; Genaidy et al., 1994; Genaidy 1991; Genaidy et al., 1990a; Genaidy et al., 1990b; Genaidy et al., 1989; Guo et al., 1992; Sharp & Legg, 1988). The influence of improved lifting technique appears even greater as task complexity increases. Studies (Genaidy et al., 1994; Genaidy, 1991; Genaidy et al., 1990a; Genaidy et al., 1990b; Genaidy et al., 1989; Guo et al., 1992) demonstrating large improvements in manual material handling capability (34% to 1350%) use extremely complex lifting, carrying, pushing, pulling

and lowering activities. Studies (Asfour et al., 1984; Sharp & Legg, 1988) using simple, single plane, symmetric lifting tasks (but still using the same task for testing and training) show smaller performance improvements, ranging from 7% to 99%.

The only other investigation to use a traditional fitness program and test its effect on manual material handling capability was performed by Sharp et al. (1993); details are in the Background section of this paper) in which they trained and tested 18 men. Relative improvements in repetitive lifting ability (lifting 41 kg from floor to chest as many times as possible in 10 minutes) averaged 17%, similar to those found in our study, despite differences in the task.

Comparisons between this study and that of Sharp et al. (1993) in maximum floor-to-chest lift are shown in Table 8. On the pretraining floor-to-chest lift, women in our study had 67% the strength of men in the Sharp et al. study. This is similar to the 60% value found in another investigation that made direct comparisons (Myers et al., 1984). After training, absolute increases in lifting capacity for the women in our study were only about 1/2 those of the men in the Sharp et al. study. Relative improvements were also slightly lower in our study (16% versus 22%).

Differences between this study and that of Sharp et al. in floor-to-chest gains may be explained both in terms of dissimilarities between the two training program and gender differences. Training volume was greater in the Sharp et al. study since subjects performed 3 to 5 sets during the entire 12 weeks of training, as opposed to the 3 sets our subjects were performing by the third week of training. Also, Sharp et al. did not include aerobic training in their exercise routine. It has been demonstrated that aerobic training can interfere with strength improvements (Dudley & Djamil, 1985; Hickson, 1980), although the mechanism for this effect is not clear (Dudley & Fleck, 1987). Studies that have demonstrated this interference have used the same muscle groups for both forms of training. In the present study, aerobic training was running which involved primarily the lower body muscle groups. Studies indicate that the gastrocnemius, soleus, and to a lesser degree, the vastus lateralis are involved in running (Costill, Jansson, Gollnick, & Saltin, 1974). The floor-to-chest lift is probably more limited by upper body muscle groups, which would have been expected to have suffered less from an unfavorable interaction between resistance and aerobic training. A larger level of interference would be expected for the floor-to-knuckle height lift.

The potential interference between aerobic and resistance training was considered before starting the investigation. Aerobic training was included in this program for two reasons.

First, past studies indicate that both types of training are necessary to improve road marching performance (Kraemer et al., 1987). Second, subjects were volunteer soldiers who must take an APFT twice a year and achieve a passing score. The APFT includes a 3.2-km running event.

Besides differences between the two training programs, gender differences could explain a portion of the lower floor-to-chest gains in our study compared to Sharp et al. When men and women exercise in similar training programs, men generally show greater absolute strength gains (Cureton et al., 1988; Gettman et al., 1982; Hunter, 1985; O'Shea & Wegner, 1981; Wilmore, 1974; Wilmore et al., 1978). This is presumably because men have a larger muscle mass (Cureton et al., 1988; Jackson & Pollock, 1978; Jackson, Pollock, & Ward, 1980; Knapik, Staab, & Harman, 1995; Maughan, Watson, & Weir, 1983) and can exercise with greater resistance, resulting in the greater gains.

Road March Performance

The improvement in road march performance was 4% in the present study. Another study (Kraemer et al., 1987) that examined the influence of combined resistance and aerobic training on road march performance found improvements of 11 to 15%. These greater improvements may be attributable to differences in the load carriage task or differences in the training program. In the study by Kraemer et al., the load carriage task involved completing a 3.2-km distance while carrying a 46-kg load, as opposed to the 5-km, 23-kg load in this study.

Also, the training volume was considerably greater in the study by Kraemer et al. Subjects performed aerobic and resistance training, both 4 days per week. In this study, the average training frequency was 3 and 2 days per week for resistance and aerobic training, respectively. In the study by Kraemer et al. aerobic training involved 40 minutes of continuous running, and subjects attempted to increase distance each time; intervals involved running 402 and 805 meters (440 and 880 yards) and occupied 20% of the total aerobic training volume. In the present study, aerobic training was about 30 minutes on average; interval training was not introduced until the sixth week and involved about 17% of the total training volume after this time. In Kraemer et al. resistance training involved more repetitions and a greater number of exercises (16 versus 9 exercises).

While improvements in this study were smaller than those of Kraemer et al. (1987) the results confirm that a traditional physical training program can increase road marching performance even if road marching is not included in the training program. It further extends these findings to show that women can increase

their road march performance if they exercise for only 1 hour per day, 5 days per week and use both resistance training and aerobic training.

CONCLUSIONS

Data analysis is continuing. We need to complete analysis of the anthropometry, body composition, exercise adherence, strength, APFT and nutritional intake data. At this point we can say that a well designed 14-week physical fitness program, conducted within the time normally allotted to physical training in the U.S. Army, can substantially improve women's MMH capability and can result in small improvements in road marching ability.

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TABLE 1.
CHANGES IN STRENGTH
IN VARIOUS RESISTANCE TRAINING STUDIES

STUDY	TRAINING PROGRAM	STRENGTH CHANGES				
		EXERCISE	ABSOLUTE (KG PRE->KG POST)		RELATIVE (%Δ)	
			M	F	M	F
(Capen, et al., 1961)	10 WKS, 3 TIMES/WK, REST OF PROGRAM UNSPECIFIED	HAND GRIP		34->36		6
		HAND GRIP		28->30		7
		BACK		104->110		11
		LEG		250->321		25
(Brown & Wilmore, 1974)	24 WKS, 3 TIMES/WK, (8WKS-6SETS: 10,8,7,6,5,4 REPS) (16WKS-5SETS: 10,6,5,4,3 REPS)	BENCH PRESS		50->68		38
		HALF SQUAT		124->160		29
(Wilmore , 1974)	10 WKS, 2 TIMES/WK, 2 SETS:7-16 REPS	LEG PRESS	407->513	229->387	26	30
		ARM CURL	39->46	20->22	19	11
		BENCH PRESS	66->77	25->32	17	29
		HAND GRIP	51->54	29->33	5	13
(Mayhew & Gross, 1974)	9 WKS, 3 TIMES/WK, 2 SETS:10 RM (CIRCUIT TRAINING)	LEG PRESS		75->110		48
		BENCH PRESS		22->28		27
		ARM CURL		12->17		39
		HAND GRIP		35->38		7

TABLE 1 (continued).
CHANGES IN STRENGTH IN VARIOUS RESISTANCE TRAINING STUDIES

STUDY	TRAINING PROGRAM	STRENGTH CHANGES				
		EXERCISES	ABSOLUTE (KG PRE->KG POST)		RELATIVE (%Δ)	
			M	F	M	F
(Wilmore, et al., 1978)	10 WKS, 3 TIMES/WK, 3 SETS: 40-55% OF 1 RM (CIRCUIT TRAINING)	BENCH PRESS	64->70	31->38	8	20
		SHOULDER PRESS	53->56	30->34	6	14
		ARM CURL	35->39	NT	11	NT
		UPRIGHT ROW	46->49	24->27	6	12
		LAT PULL	68->73	26->35	7	36
		LEG PRESS	185->197	84->107	7	27
		LEG CURL	39->42	19->29	6	53
		LEG EXTENSION	66->76	NT	15	NT
(Cureton, et al., 1988)	9 WKS, 3 TIMES/WK, 2 SETS OF 10 RM	ARM CURL	32->42	16->25	36	59
		TRICEPS EXTENSION	33->43	18->25	35	42
		LEG CURL	65->73	34->42	13	24
		LEG EXTENSION	80->105	42->58	29	34
(Bailey, Byrnes, Dickinson, & Foster, 1987)	10 WKS, 4 TIMES/WK, 3 SETS OF 80% 1RM	LEG PRESS		NR		21
		LEG EXTENSION		NR		50
(O'Shea & Wegner, 1981)	7 WEEKS, 3 TIMES/WK: 2 DAYS-70% 1RM, 4SETS, 5 REPS; 1 DAY-50% 1RM, 3 SETS, 6-8 REPS	BENCH PRESS	88->95	43->49	8	13
		SQUAT	104->124	76->96	16	24

NR=Not Reported, NT=Not Tested

TABLE 1 (continued).
CHANGES IN STRENGTH
IN VARIOUS RESISTANCE TRAINING STUDIES

STUDY	TRAINING PROGRAM	STRENGTH CHANGES				
		EXERCISES	ABSOLUTE (KG PRE->KG POST)		RELATIVE (%Δ)	
			M	F	M	F
(Hunter, 1985)	7 WEEKS, 2 GROUPS: 3 TIMES/WK, 3 SETS, 7-10 REPS; 4 TIMES/WK, 2 SETS, 7-10 REPS	BENCH PRESS (3/WK)	69->77	26->31	12	20
		BENCH PRESS (4/WK)	59->69	27->36	17	34
(Oyster, 1979)	7 WEEKS, 2 TIMES/WK, REST OF PROGRAM UNSPECIFIED	SHOULDER FLEXION		65->69		6
		SHOULDER EXTENSION		74->75		1
		ELBOW FLEXION		104->95		-9
		ELBOW EXTENSION		50->48		-4
		KNEE EXTENSION		165->247		50
		ANKLE P. FLEX		194->247		27
		HIP FLEXION		100->120		20
		HAND GRIP		79->87		10
(Stone & Coulter, 1994)	9 WEEKS, 3 TIMES/WK, 3 GROUPS: 3 SETS, 6-8 REPS; 2SETS, 15-20 REPS; 1 SET, 30-40 REPS	BP (3SET)		29->35		19
		SQUAT		52->69		33
		BP (2SET)		31->37		17
		SQUAT		49->64		31
		BP (2SET)		33->37		12
		SQUAT		59->74		25

TABLE 1 (continued)
CHANGES IN STRENGTH
IN VARIOUS RESISTANCE TRAINING STUDIES

STUDY	TRAINING PROGRAM	STRENGTH CHANGES				
		EXERCISES	ABSOLUTE (KG PRE->KG POST)		RELATIVE (%Δ)	
			M	F	M	F
(Butts & Price, 1994)	12 WEEKS, 3 TIMES/WK, 1 SET OF 8-10 REP MAX (NAUTILUS MACHINES)	HIP&BACK		NO 1RM		NO 1RM
		LEG EXT				
		LEG CURL				
		CHEST				
		PULLOVER				
		MULTICURL				
		MULTI-TRI				
		ABDOMINAL				
(Gettman , et al., 1982)	12 WEEKS, 3 TIMES/WK 3 SETS OF 12-15 REPS OF 40% OF 1RM (CIRCUIT TRAINING)	BENCH PRESS (CWT*)	66->75	30->36	14	20
		LEG PRESS (CWT)	196->227	113->133	16	18
		BENCH PRESS (CWT&RUN)	68->82	29->35	21	21
		LEG PRESS (CWT&RUN)	191->232	104->131	21	26

*CWT=Circuit Weight Training

TABLE 2.
CHANGES IN BODY COMPOSITION FOLLOWING RESISTANCE TRAINING

STUDY	GROUP	RELATIVE (%Δ) BODY COMPOSITION CHANGES				ABSOLUTE (KGΔ) BODY COMPOSITION CHANGES			
		FAT FREE MASS		BODY FAT		FAT FREE MASS		BODY FAT	
		M	F	M	F	M	F	M	F
(Brown & Wilmore, 1974)			+1.7		-3		+1.0		-1
(Wilmore, 1974)		+1.9	+2.4	-10	-8	+1.1	+1.2	-1	-1
(Mayhew & Gross, 1974)			+3.7		-7		+1.5		-2
(Bailey, et al., 1987)			+2.0				NR*		
(O'Shea & Wegner, 1981)			+0.6		+2.3		+0.3		+0.6
(Hunter, 1985)		+0.7	+0.6	-2	-7	+0.5	+0.3	-1	-1
(Butts & Price, 1994)			+2.9		-7.4		+1.3		-2.2
(Gettman, et al., 1982)	CWT**	+2.3	+3.9	-18.2	-10.4	+2.7	+1.9	-3.8	-1.9
	CWT & RUN	+2.7	+2.2	-14.8	-12.7	+2.3	+1.0	-2.9	-2.3

*NR=Not Reported **CWT=Circuit Weight Training

TABLE 3.
SELECTED CHANGES IN BODY GIRTH AS A RESULT OF RESISTANCE TRAINING

STUDY	RELATIVE GIRTH CHANGES (%Δ)		
	MEASURES	M	F
(Brown & Wilmore, 1974)	THIGH		0.3
	CALF		1.8
	DELTOID		5.9
	BICEPS (FLEXED)		1.6
	BICEPS (EXTENDED)		3.1
	FOREARM		0.8
(Wilmore, 1974)	THIGH	0.5	0.4
	CALF	0	0.3
	DELTOID	2.7	1.3
	BICEPS (FLEXED)	2.4	2.2
	BICEPS (EXTENDED)	2.4	2.4
	FOREARM	1.8	0.4
	ABDOMEN	0.7	0.9
(Mayhew & Gross, 1974)	FOREARM		2.1
	BICEPS		2.7
	SHOULDER		2.0
	CHEST		3.1
(Bailey, et al., 1987)	THIGH		1
(Hunter, 1985)	BICEPS	2.9	2.5
	CHEST	1.2	-0.8
(Oyster, 1979)	BICEPS (RELAXED)		-1.4
	CHEST (RELAXED)		-1.2
	DELTOID		-0.9
	THIGH		-1.8
	CALF		-3

TABLE 4

PRETRAINING TRIALS FOR MANUAL MATERIAL HANDLING TASKS

		TRIAL 1	TRIAL 2	TRIAL 3	p- VALUE ^a	CRITICAL DIFFERENCE ^b
FLOOR TO KNUCKLE MAX LIFT (KG)	M	61.8	68.1	68.6	0.012	4.8 (p=0.05) 6.6 (p=0.01)
	SD	14.8	10.3	9.0		
FLOOR TO CHEST MAX LIFT (KG)	M	44.6	48.9	48.8	0.001	2.2 (p=0.05) 3.0 (p=0.01)
	SD	6.5	6.1	6.5		
REPETITIVE LIFT AT 5 MINUTES (REPS)	M	81.7	87.1	87.1	0.005	3.5 (p=0.05) 4.7 (p=0.01)
	SD	5.0	9.8	9.6		
REPETITIVE LIFT AT 10 MINUTES (REPS)	M	154.2	164.6	168.5	>0.001	4.8 (p=0.05) 6.6 (p=0.01)
	SD	14.8	20.1	20.1		

^a From Repeated Measures Analysis of Variance^b From Tukey Test

TABLE 5

POSTTRAINING TRIALS FOR
THE MANUAL MATERIAL HANDLING TASKS

		TRIAL 1	TRIAL 2	p-VALUE ^a
FLOOR TO KNUCKLE MAX LIFT (KG)	M	82.0	80.4	0.196
	SD	9.9	12.2	
FLOOR TO CHEST MAX LIFT (KG)	M	55.9	57.2	0.414
	SD	5.3	7.4	
REPETITIVE LIFT AT 5 MINUTES (REPS)	M	98.9	102.0	0.074
	SD	9.7	10.6	
REPETITIVE LIFT AT 10 MINUTES (REPS)	M	191.3	195.8	0.120
	SD	24.2	24.5	

^a From Repeated Measures Analysis of Variance

TABLE 6
PRETRAINING AND POSTTRAINING SCORES FOR
THE MANUAL MATERIAL HANDLING TASKS

		PRETRAINING SCORE	POSTTRAINING SCORE	p-VALUE ^a
FLOOR TO KNUCKLE MAX LIFT (KG)	M	68.4	81.2	>0.001
	SD	9.3	10.9	
FLOOR TO CHEST MAX LIFT (KG)	M	48.8	56.6	>0.001
	SD	5.3	5.9	
REPETITIVE LIFT AT 5 MINUTES (REPS)	M	87.1	100.5	>0.001
	SD	9.3	9.8	
REPETITIVE LIFT AT 10 MINUTES (REPS)	M	166.6	194.5	>0.001
	SD	19.8	24.1	

^a From Paired T-Test

TABLE 7
ROAD MARCH TIMES

		1 KM	2 KM	3 KM	4 KM	5 KM
PRETRAINING ROAD MARCH (MIN)	M	8.7	17.9	26.9	36.2	44.7
	SD	0.8	1.3	1.8	2.3	2.8
POSTTRAINING ROAD MARCH (MIN)	M	8.8	17.7	26.4	35.3	43.1
	SD	1.1	2.0	2.9	3.6	4.1

TABLE 8

COMPARISONS BETWEEN PRESENT STUDY AND SHARP ET AL.
FOR MAXIMUM FLOOR-TO-CHEST LIFT

STUDY	PRETRAINING (KG)	POSTTRAINING (KG)	Δ (KG)	Δ (%)
PRESENT	48.8	56.6	7.8	16.0
(Sharp, et al., 1993)	73.0	89.0	16.0	21.9
PRESENT/ (Sharp, et al., 1993)	0.668	0.636	0.488	